Synopsis

X-ray observations of cosmic sources started with rockets and balloon missions about half a century back. *UHURU* - the first X-ray satellite mission was launched in 1970. The last 15-20 years may be considered as the golden age of X-ray astronomy as dedicated X-ray astronomy satellites brought advancement in observations which helped to understand the mechanisms responsible for X-ray emission. Various objects in the sky produce X-rays, like X-ray binary systems, Active Galactic Nuclei (AGN), Supernova remnants etc. X-rays are produced by various mechanisms like synchrotron radiation, black body radiation, inverse Compton and bremsstrahlung radiation. This thesis studies X-ray binary systems.

Majority of the brightest objects in the X-ray sky are X-ray binary systems. These gravitationally bound systems consist of a compact object and a normal star. The compact object may be a white dwarf, a neutron star or a black hole. Here accretion is the main source of energy which can happen via stellar wind or Roche lobe overflow. The accreted matter falls onto the compact object and gravitational potential energy lost by the accreted matter is converted into X-rays. Such self gravitating, extremely dense and some times highly magnetic objects provide physical conditions that are difficult to reproduce in a terrestrial laboratory. So they are the laboratories to study these extreme conditions.

Based on the mass of the companion, X-ray binary systems are classified into High Mass X-ray binaries (HMXBs), Low Mass X-ray binaries (LMXBs) and Intermediate Mass X-ray binaries (IMXBs). If the mass of the companion star is $>10\,M\odot$ then it will be a HMXB and if it is $\leq 1M\odot$ it will be LMXB and if the mass is between these two limits then it will be treated as an IMXB. Based on the type of companion star HMXBs are again classified into Be systems and supergiant systems. If the companion is a supergiant, mass transfer occurs by stellar winds and if it is a Be star the process will be different. Be stars have a cicrumstellar disk at the equator and these systems have mostly eccentric binary orbits. If the compact object passes by the disc, there will be more accretion, producing outbursts of X-rays. There are two types of outbursts in Be X-ray binaries, Type I and Type II. When the neutron star crosses the circumstellar disc during periastron passage it produces periodic outbursts which are called Type I. They last for a fraction of the orbital period and occur at a particular orbital phase of the neutron star when the luminosity increases by a factor of ~ 10 from the quiescent stage. If there is a large mass outflow, a Be star forms a decretion disk from which the compact object accretes mass and Type II outbursts are produced. These are giant ones, lasting

for a few weeks, cover a large fraction of the orbital period and can occur at any phase of the neutron star's orbit. Here the luminosity increases by a factor 10^2 to 10^3 compared to the persistent level. Those with Be star companions are transient in nature while supergiant X-ray binaries are usually persistent ones. Supergiant Fast X-ray Transients are a class of HMXBs associated with OB supergiants. Almost all HMXBs are in the class of accretion powered pulsars (APPs). The compact stars in these systems have a strong magnetic field and the accreted matter is guided by these field lines and falls onto the poles of the neutron star and the loss in gravitational potential energy is released as X-rays. As the neutron star rotates, the beam of radiation crosses the observer's line of sight resulting in X-ray pulses. But in the case of LMXBs the accretion happens via Roche-lobe overflow. The accreted matter forms a disc around the compact object conserving angular momentum while loosing energy and spirals towards the surface of the neutron star. In these systems the magnetic fields are in the range of 10^8 to 10^{11} G but in the case of HMXBs it is quite high - around 10^{12} G. Only very few IMXBs have been detected so far.

In addition to having periodic pulses, these X-ray sources can be highly variable and the variations may be aperiodic or quasi-periodic. The power density spectrum of the X-ray light curve of a pulsar shows peaks due to the pulsations and its harmonics. The quasi-periodic oscillations (QPOs) in the X-ray intensity produce broader features in the power density spectrum. In many pulsars the power density spectrum shows changes in its shape with changes in the X-ray intensity. The power density spectrum, tracking the variations in the accretion process over a wide range of frequency, is therefore a very powerful probe of the X-ray emission mechanism of accreting X-ray sources, including pulsars. QPOs are also helpful in estimating the magnetic fields of these pulsars.

In this work we have analysed power density spectra of all the APPs observed with the *Proportional Counter Array* (PCA) instrument of the *Rossi X-ray Timing Explorer* (RXTE) satellite, except the millisecond pulsars. Large area X-ray Detectors flown in the earlier space observatories had a few millisecond time resolution but RXTE/PCA have microsecond time resolution and this is the best instrument for timing studies in the present age. RXTE satellite brought many new insights in X-ray astronomy like *kilo*-Hertz Quasi Periodic Oscillations.

For the analysis we used `HEASOFT` software provided at the HEASARC at NASA-GSFC. From the raw data we created the light curve with a bin size of 125 ms and using this created the power density spectrum. We analysed RXTE/PCA light curves of 55 accretion powered pulsars generated from a total of 5822 observations and searched for

Quasi Periodic Oscillations (QPOs). One important outcome of the work has been the discovery of Quasi Periodic Oscillations in four transient X-ray pulsars.

The Be X-ray pulsar KS 1947+300 had a type II outburst in 2000-2001. QPOs at 0.02 Hz were detected during 2001 May-June, at the end of a long outburst. The QPO frequency of this source is the lowest among those for transient X-ray pulsars. The unusual feature of this source is that though the outburst lasted for more than 100 days, the QPOs were detected only during the last few days of the outburst, when the X-ray intensity had decayed to 1.6% of the peak intensity. The rms value of the QPO is large, $\sim$15.4$\pm$1.0% with a slight positive correlation with energy and the QPO feature is seen upto 20 keV. This transient QPO feature has a quality factor 3.6 and has a detection significance of 6σ. The detection of QPOs and strong pulsations at a low-luminosity level suggests that the magnetic field strength of the neutron star is not as high as was predicted earlier on the basis of a correlation between the spin-up torque and the X-ray luminosity. The magnetic field estimated from the X-ray luminosity and QPO frequency is about 4.2×10^{12} G.

After a long quiescence of three decades, the transient X-ray pulsar 4U 1901+03 became highly active in 2003 February and we detected QPOs and flares from this source. The 0.135 Hz QPO feature was detected at the end of the outburst. The QPO feature is broad with a quality factor of 3.3 and with an rms value of 18.5$\pm$3.1%. We also checked the energy dependence of the QPO and found that it is undetectable above 11 keV. Using the QPO frequency and the X-ray luminosity during the QPO detection period, we estimated the magnetic field strength of the neutron star as 0.31×10^{12} G which is consistent with the value inferred by other authors under the assumption of spin equilibrium. The X-ray flares detected had a duration of 100 - 300 s, showed spectral changes and were more frequent and stronger during the peak of the outburst.

We detected a persistent QPO feature in the slow Be pulsar 1A 1118-616 during the type II outburst in 2009. The QPO feature is centred at a frequency $0.07-0.09$ Hz and it lasted for 13 days. The mean rms value of the QPO is 5.2% and it shows a significant energy dependence with highest rms of 7% at 9 keV. The quality factor of the QPO is about 5.4 and detection significance is around 7σ. The QPO frequency changed from 0.09 Hz to 0.07 Hz within 10 days. The magnetic field estimated from the QPO frequency and X-ray luminosity is 3.38 $\times10^{12}$ G.

The slow pulsar GX 304-1 had a type II outburst in 2010 and we detected a persistent QPO feature at 0.125 Hz along with a harmonic. The QPO feature had a low rms value of 2.9% and it showed a positive energy dependence upto 40 keV with the rms value increasing to 9% at 40 keV. The quality factor is 7 and detection significance is about

6σ. The QPO frequency decreased from 0.128 Hz to 0.108 Hz in 12 days. Based on the QPO detection the magnetic field strength estimated as 2.1×10^{12} G.

We found that in many of the X-ray pulsars, the Power Density Spectrum (PDS) shows significant variation in the shape of the continuum and the break frequency. Often the PDS is found to evolve with time or X-ray intensity. We classify the PDS based on the shape of the continuum and also try to correlate the PDS with the spectral states of the sources.

In most of the observations during the outburst of 4U 1901+03 we detected a broadening of the pulse-frequency peak also. To understand this feature we generated pulse profiles using data over short durations at three different intensity levels of the source. We explore the possibility that the broadening of the pulse frequency peak is due to systematic intensity dependent changes in the pulse shape over short durations. This would imply a coupling between the periodic and the low-frequency aperiodic variabilities. We analysed 12 pulsars which show broadening and a few of them show differences in the pulse profiles at various intensities.

The structure of this thesis is as given below:

- In **Chapter 1** we provide an overview of X-ray binary systems and one of the main timing properties, the power density spectrum. We describes the *Rossi X-ray Timing Explorer* satellite. The data from this satellite is used in the thesis.
- **Chapter 2** describes the discovery of Quasi Periodic Oscillations in *KS 1947+300* and we estimate the magnetic field of this source using the QPO frequency and luminosity during the time of the QPO detection.
- In **Chapter 3** we report for the first time Quasi Periodic Oscillations and flares of 100−300 s in *4U 1901+03*. We also estimate the magnetic field for this source using the QPO frequency and luminosity during the time of QPO detection.
- **Chapter 4** describes the 0.09 Hz QPO feature detected in *1A 1118-616* and estimate the magnetic field for this source using the QPO frequency and luminosity during the time of QPO detection.
- In **Chapter 5** we discuss the discovery of Quasi Periodic Oscillations in *GX 304−1* and estimate the magnetic field for the source using the QPO frequency and luminosity during the time of QPO detection.

- In **Chapter 6** we make a comparative study of the strength of the magnetic field estimated using the X-ray luminosity during the time of the QPO detection and that determined from the observed cyclotron line features.
- **Chapter 7** provides an analysis of power density spectra of 26 Accretion Powered Pulsars and classify them based on the shape of the power density spectra.
- In **Chapter 8** we discuss the relation between broadening of the pulse frequency peak and intensity dependent pulse profiles of 12 pulsars.
- **Chapter 9** gives our findings and discusses the scope of future work with ASTROSAT/LAXPC.